Meridional progression of interannual oscillations in summer Arctic TOA fluxes

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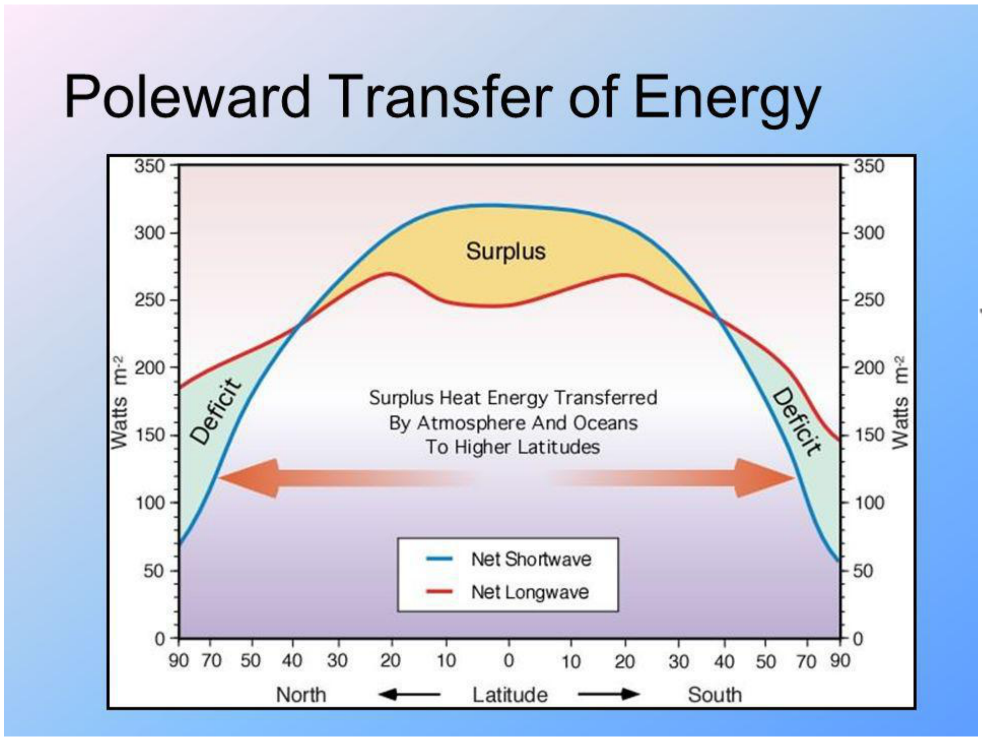
Outline

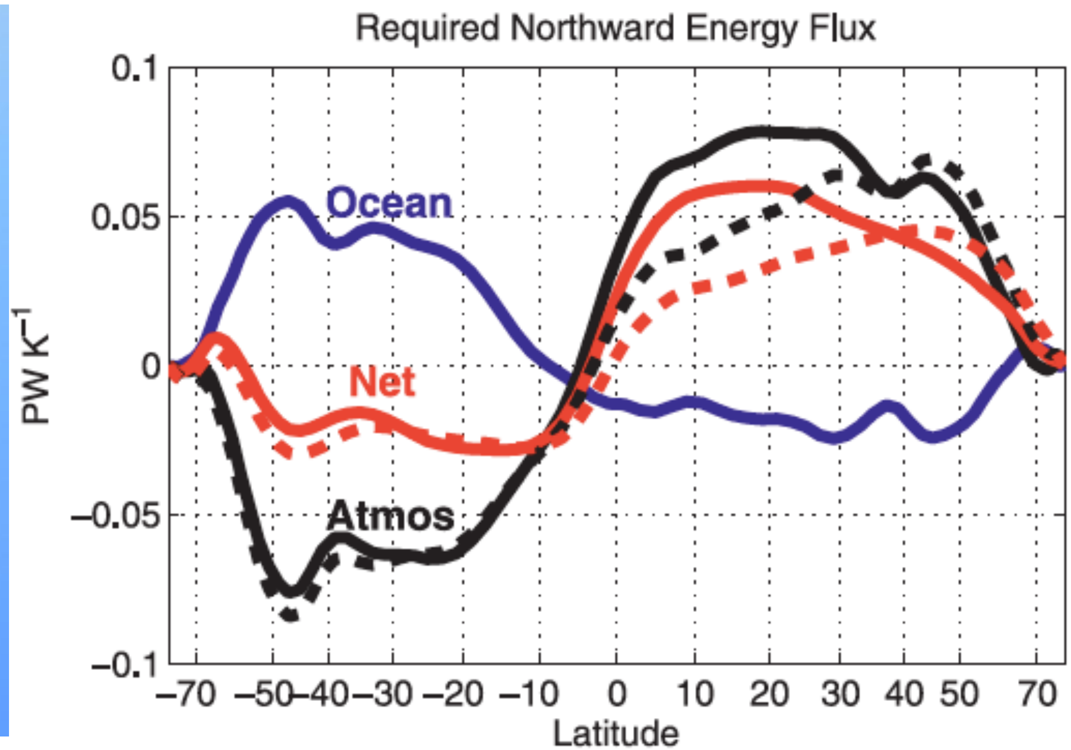
- CERES TOA fluxes over the Arctic
  - Summertime interannual oscillations
  - Arctic warming -> albedo decrease
    (lost of perennial ice/snow cover)
  - Open Arctic Ocean -> Increasing atmos-ocean-cryo couplings
- Pole and mid-latitude connections
  - Teleconnection: poleward heat/moisture transport
  - New Arctic -> mid-latitude weather/climate
- "Centers of action"
  - Where is the most vulnerable place in terms of TOA radiation as the Arctic warms?
  - What are their impacts?

Equator-to-Pole Heat Transport: A one-way traffic?

“Ocean”=sum of oceanic poleward flux and heat storage



Credit: Georgia State U



Zelinka and Hartmann (2012)

Arctic Energy Accumulation

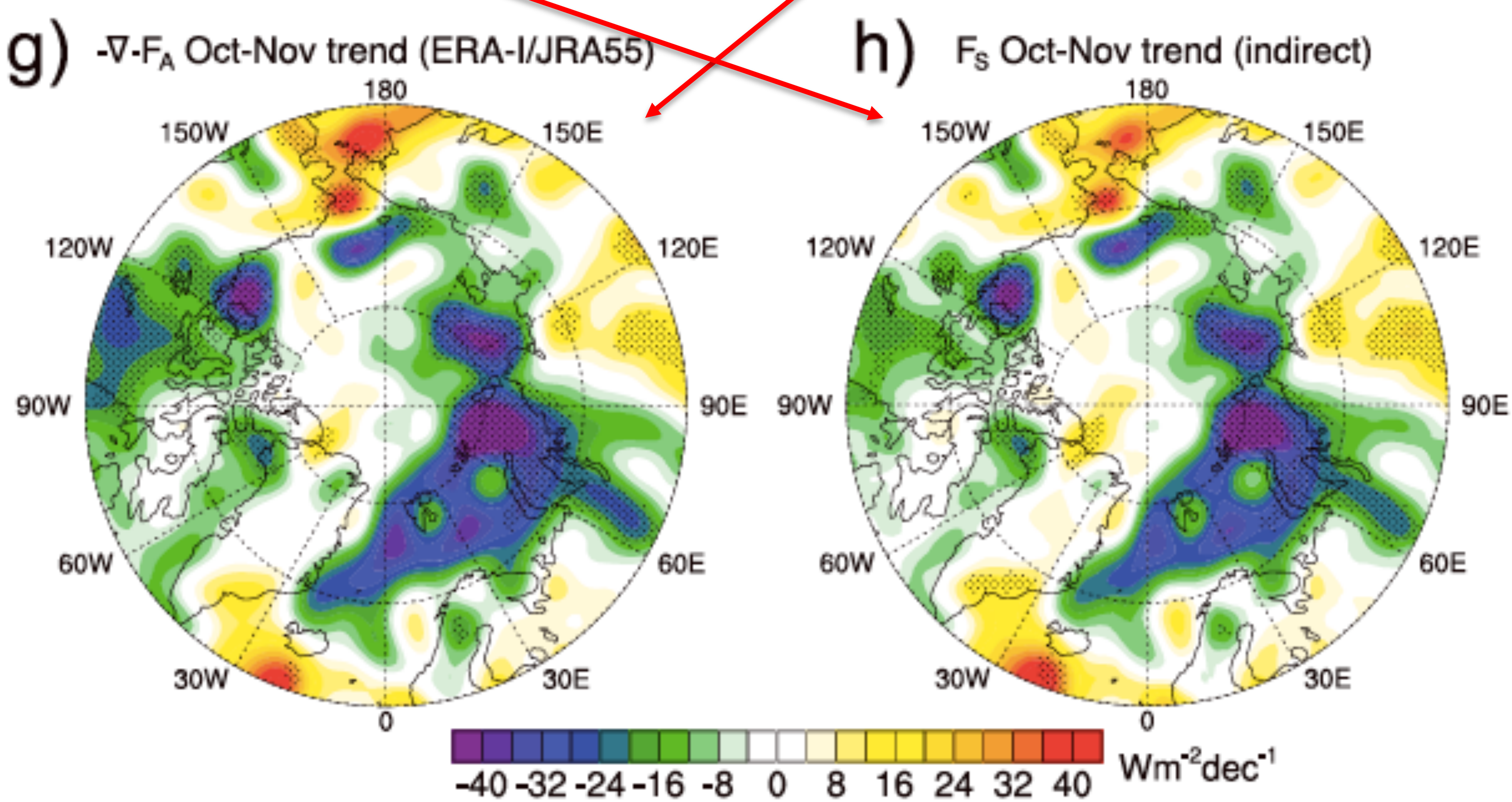
(Mayer et al., 2016)

Net Surface Flux

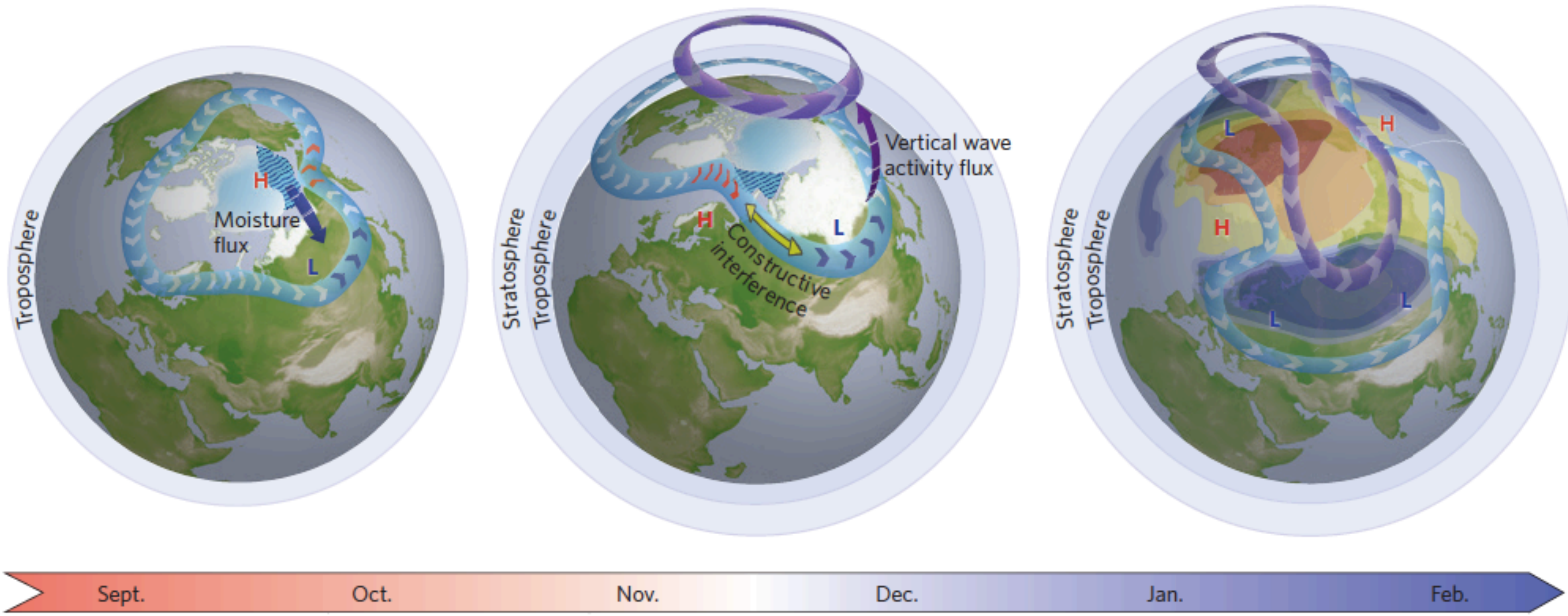
Converge of Atmospheric Energy Transport

Rate of Atmospheric Energy Storage

$$\boxed{F_S = Rad_{TOA} - \nabla \cdot F_A - AET}$$



Arctic Warming and Mid-Latitude Extreme Weather



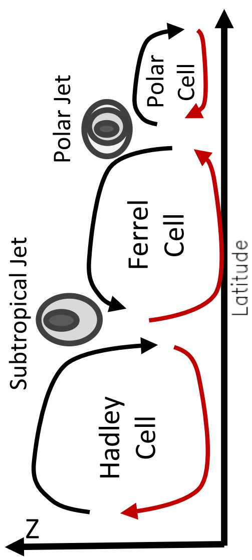
Cryospheric forcing and constructive interference with atmospheric dynamics

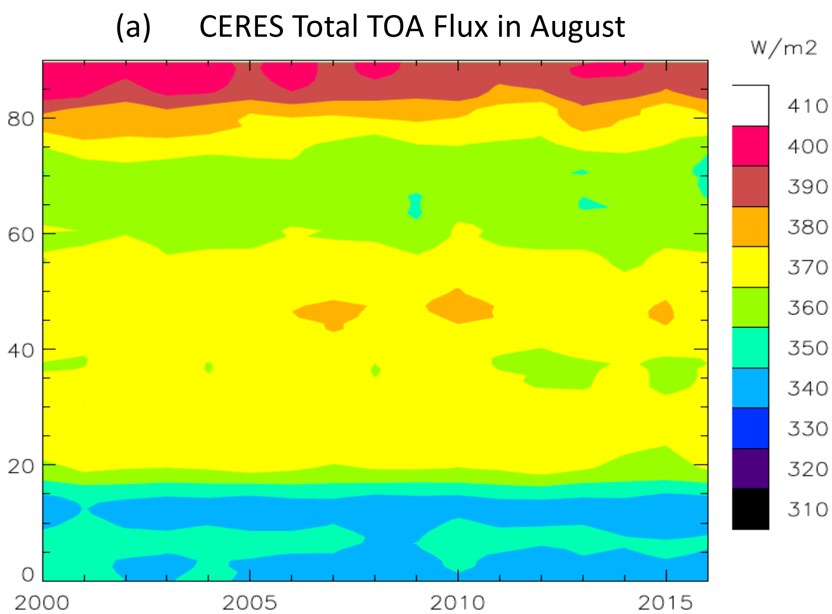
Cohen et al. (2014)

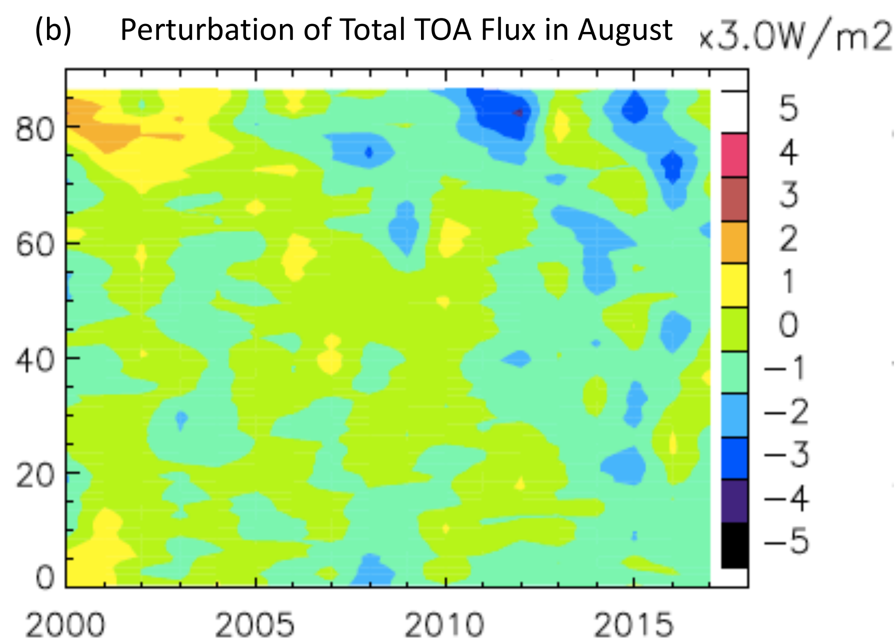
https://usclivar.org/meetings/2017-arctic-midlatitude-workshop-agenda

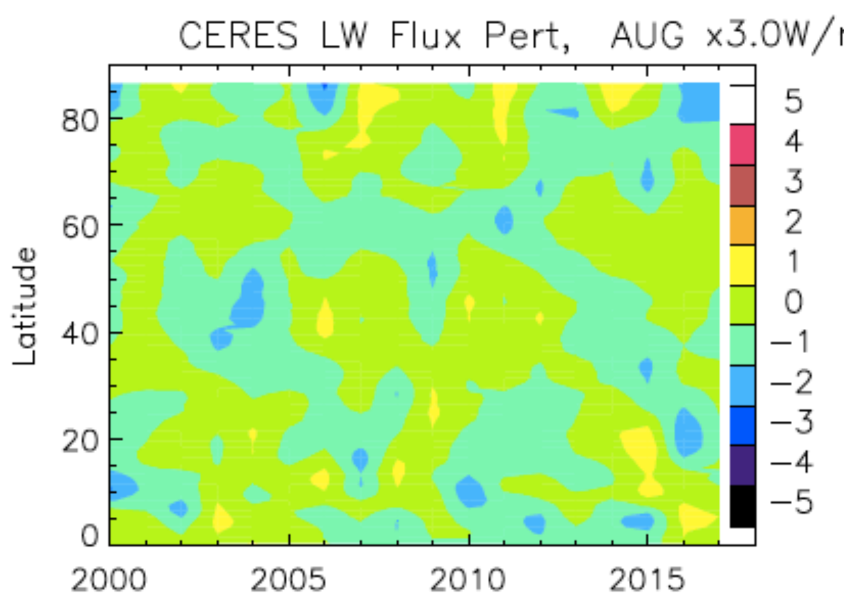
CERES TOA Fluxes

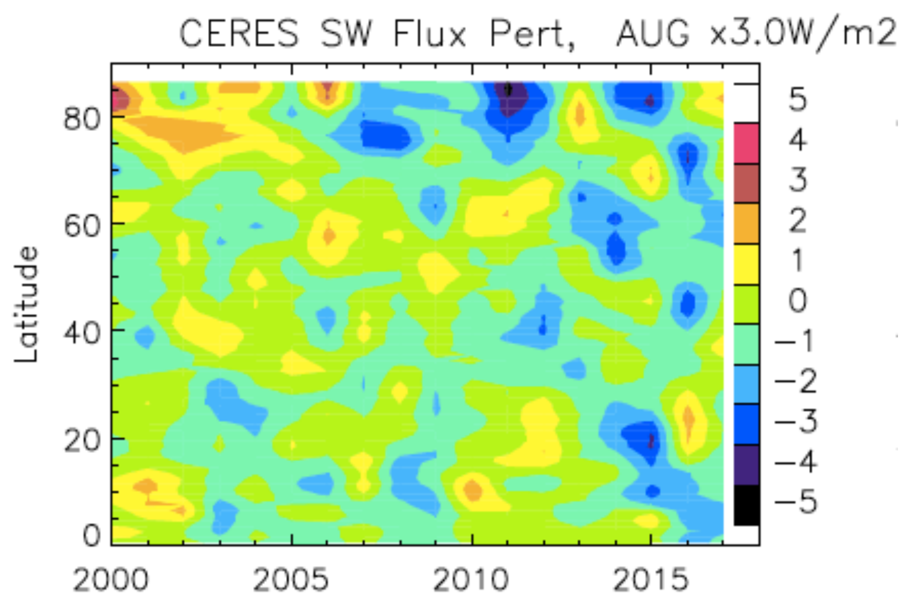
(Northern Hemispheric Augusts)





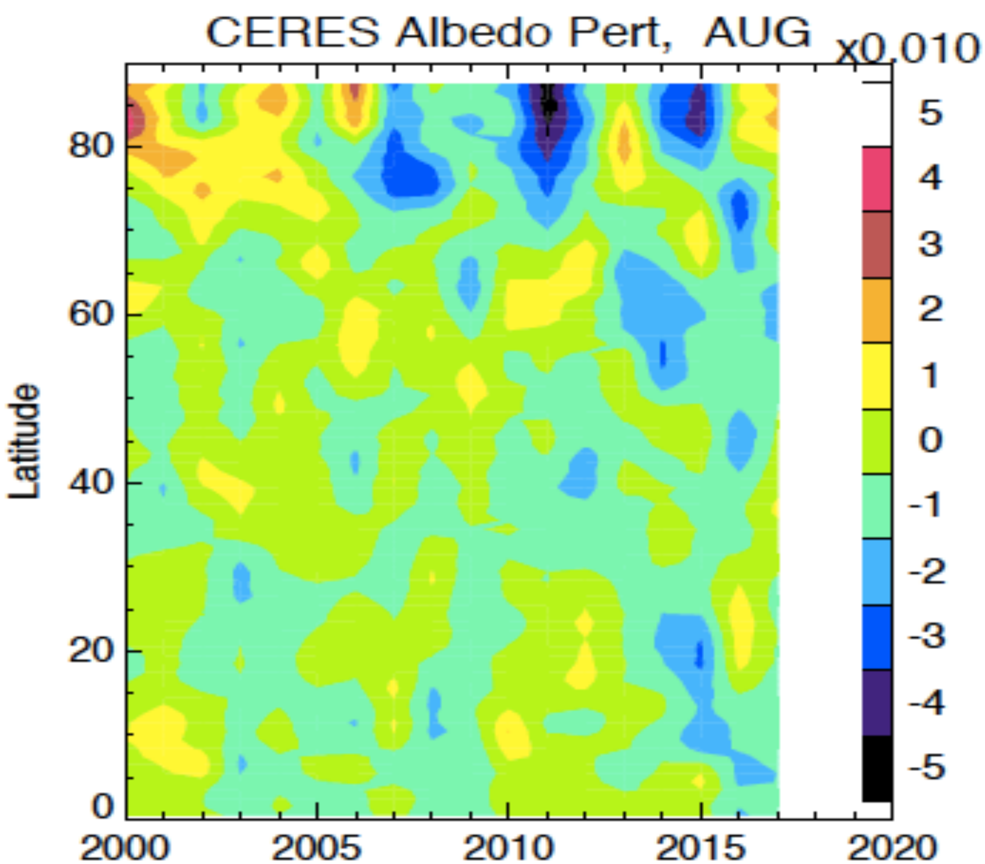


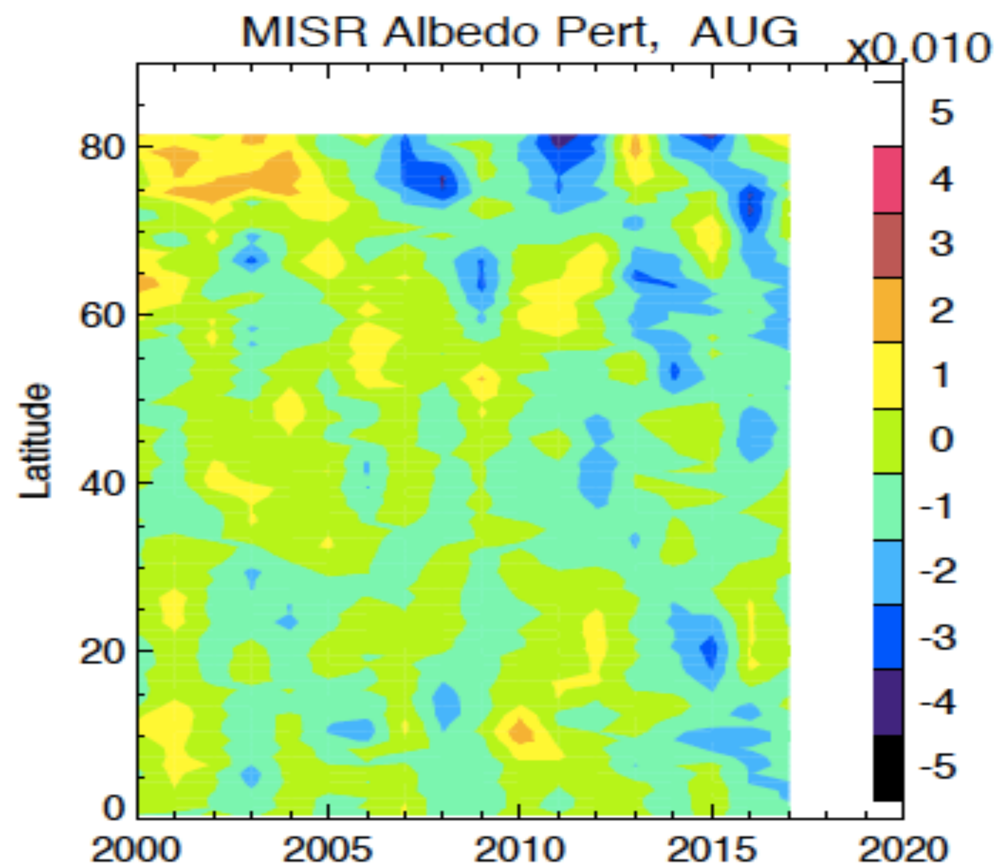




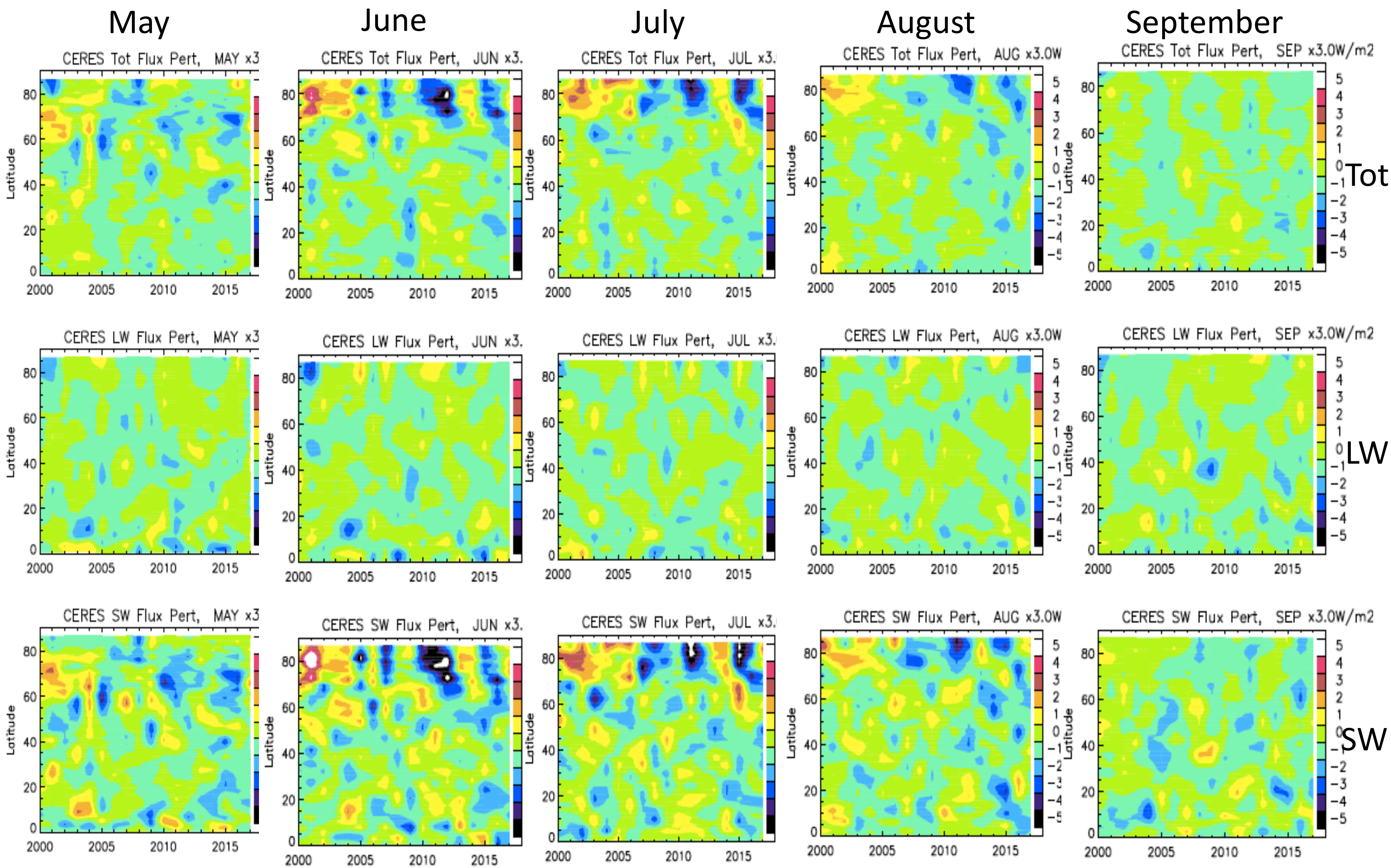
Consistency Check:
CERES and MISR SW Albedos

- CERES
  - Broad band SW measurements
  - Angular distribution function (ADM) models
- MISR
  - Narrow-to-broad band model
  - Multi-angle measurements



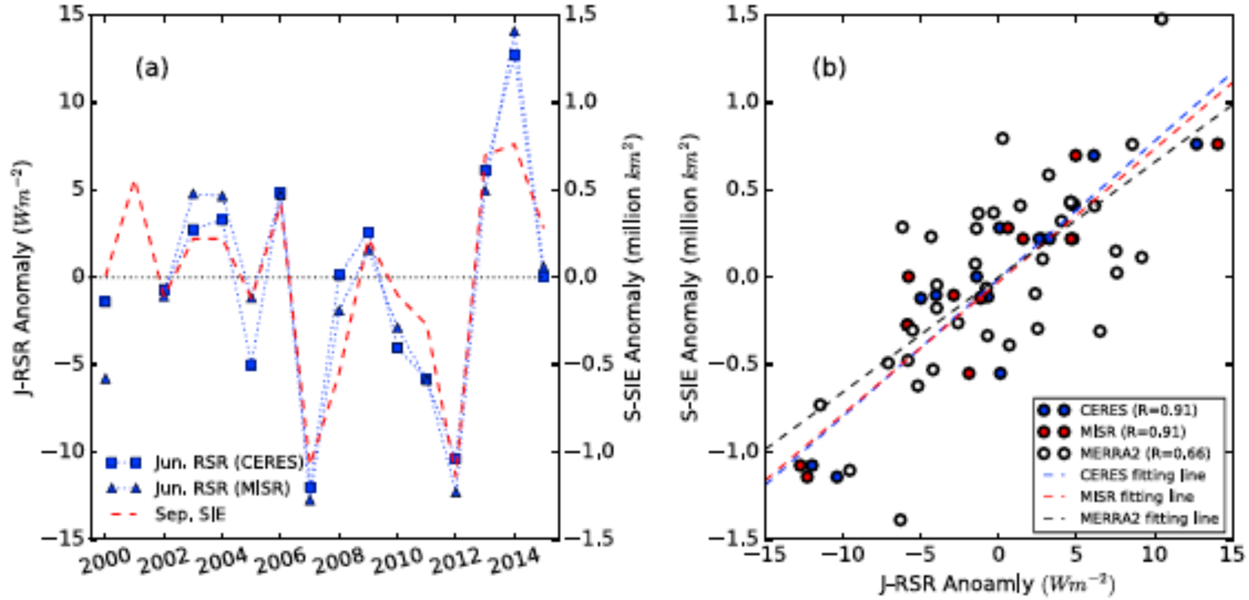


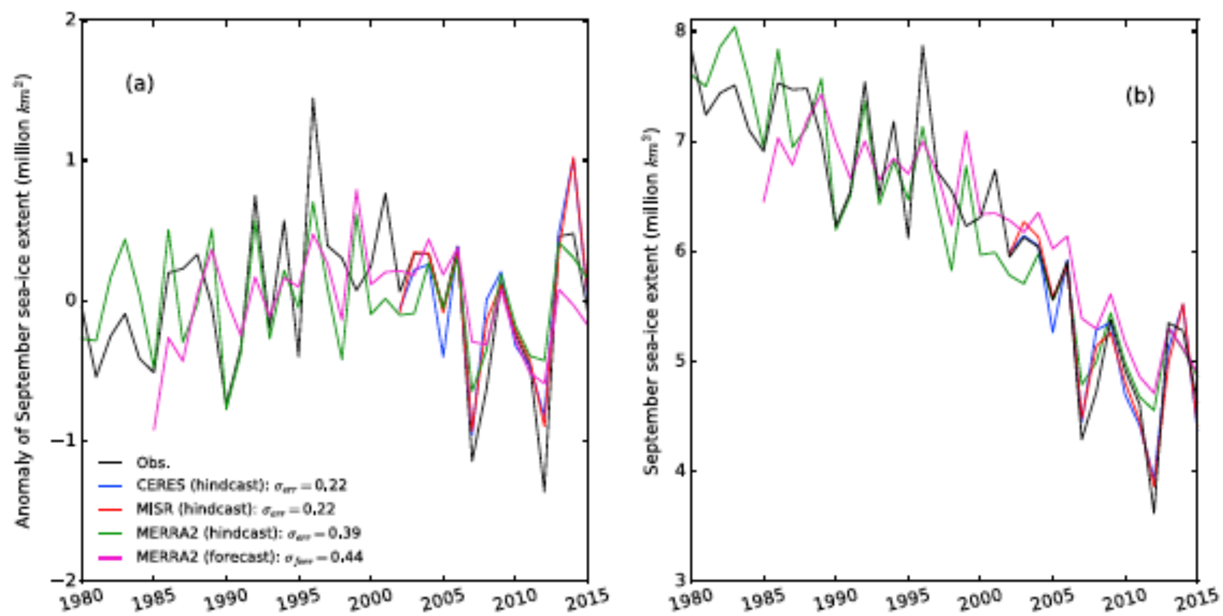
Interannual Variability by Month



Importance of June TOA Flux

- Strong correlation (r=0.91) between Arctic <u>June</u> SW TOA flux and <u>September</u> sea ice extent (SIE)
- June SW TOA flux as an empirical predictor of September SIE for field campaign and shipping planning



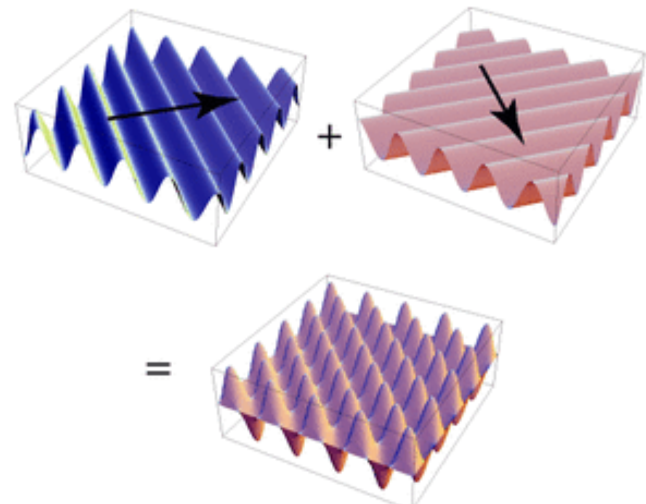


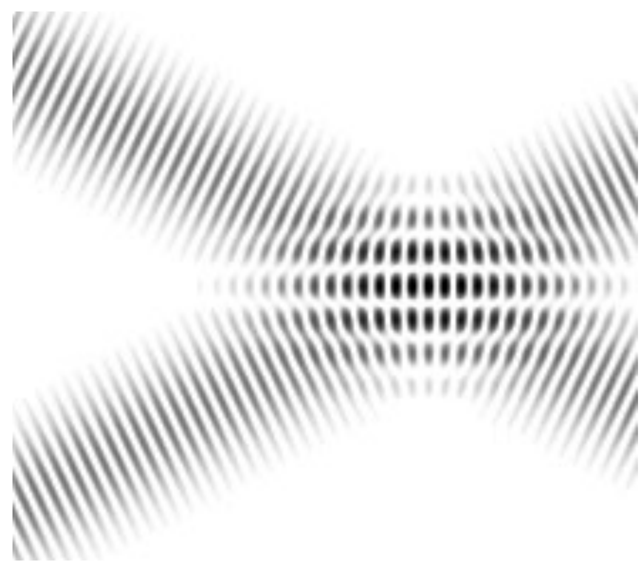
Zhan and Davies (2017)

Method:

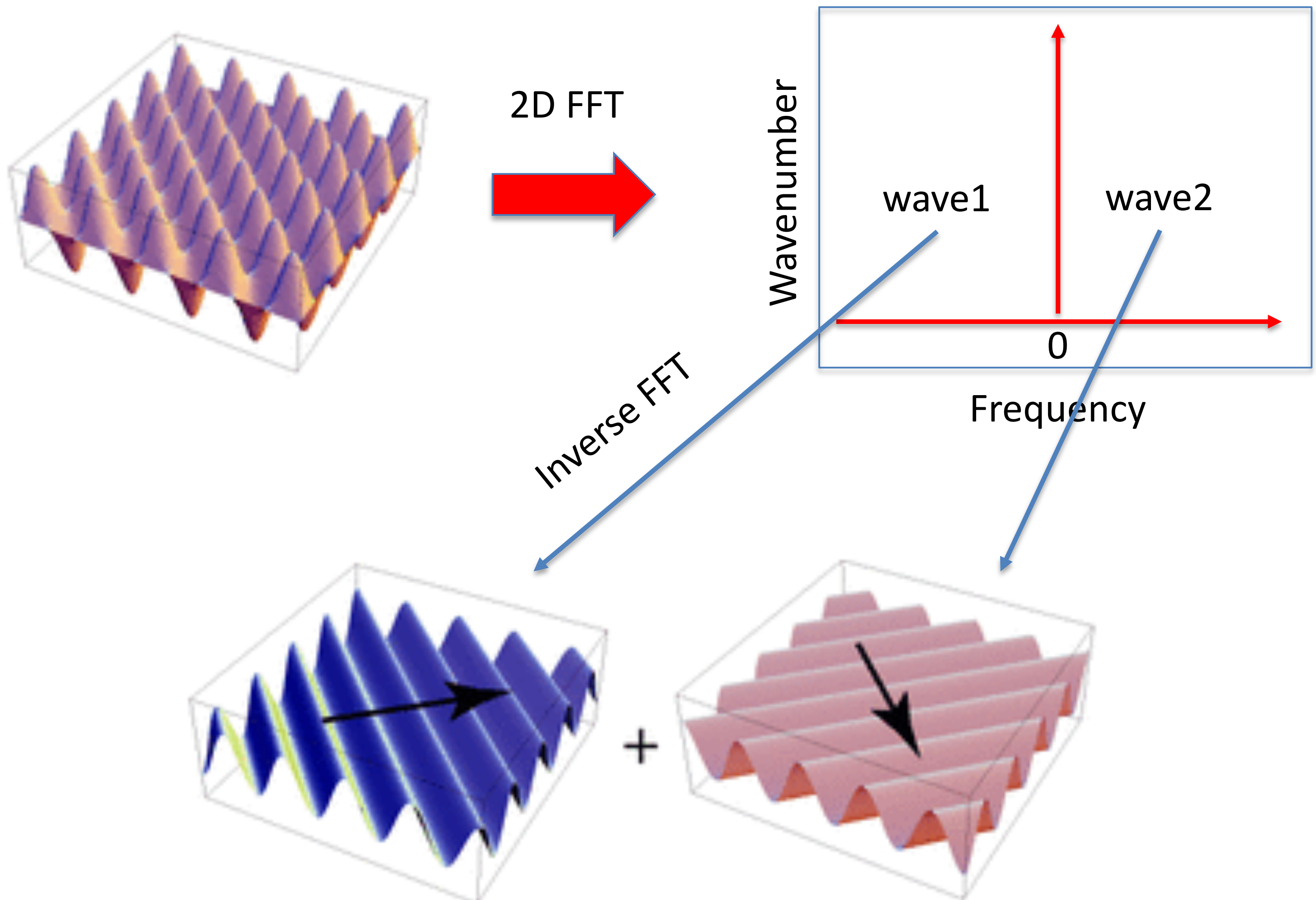
Wave Decomposition -> Processes

- 2D-FFT to split/combine orthogonal wave components
- Time-latitude series: poleward and equatorward components
- What processes affect mid-latitude TOA flux variabilities?

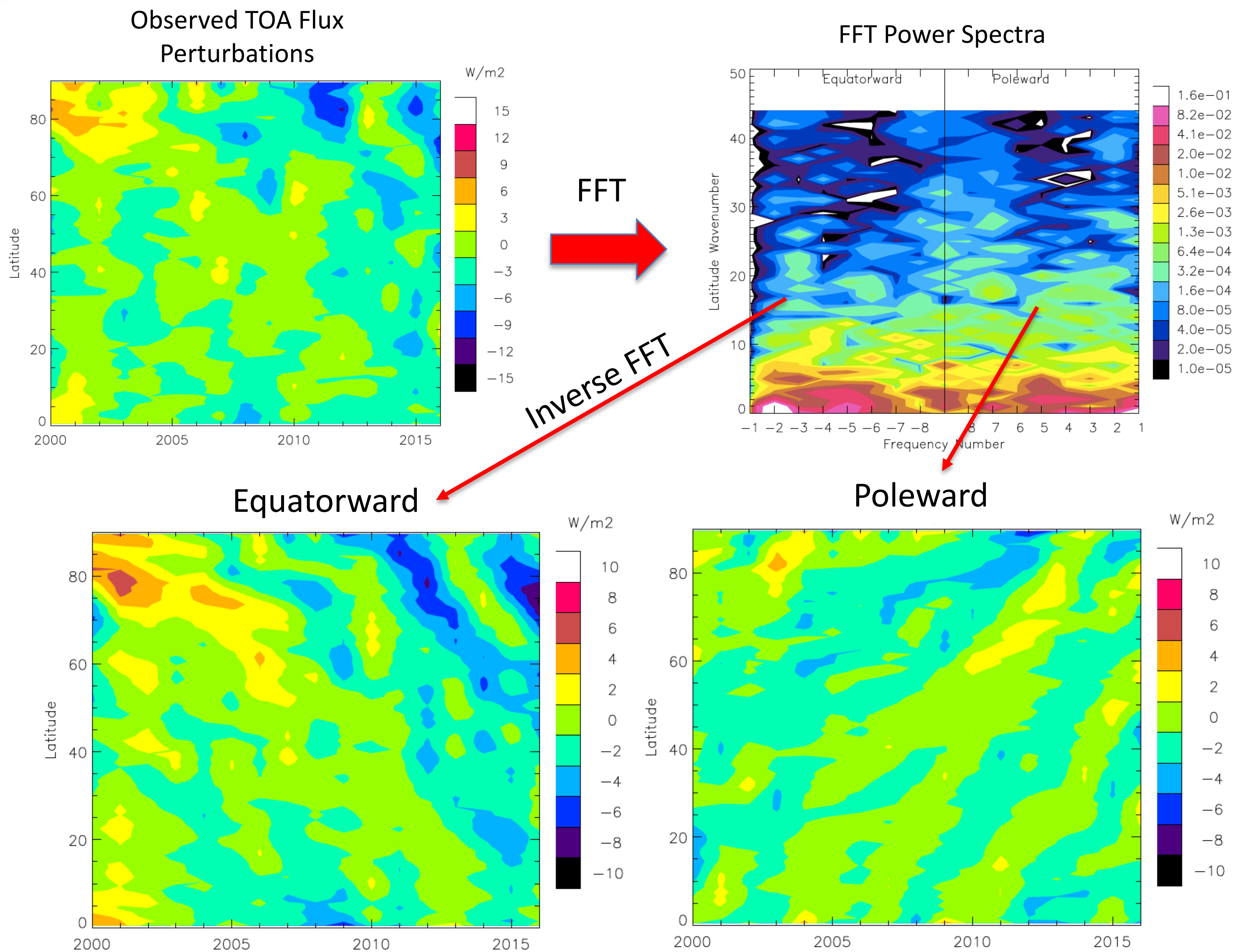




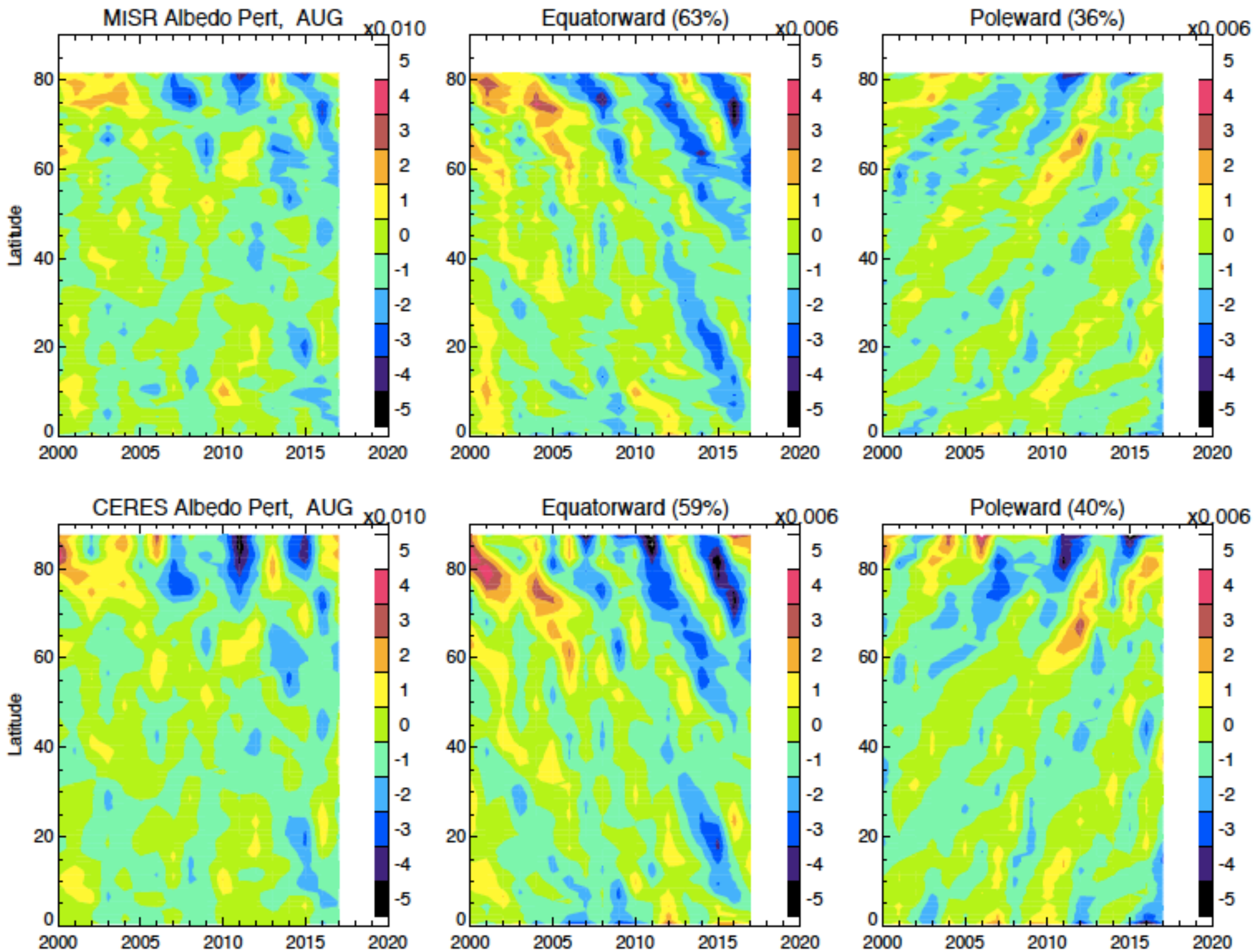
2D FFT for Wave Decomposition



Decomposition of CERES TOA Flux Variations

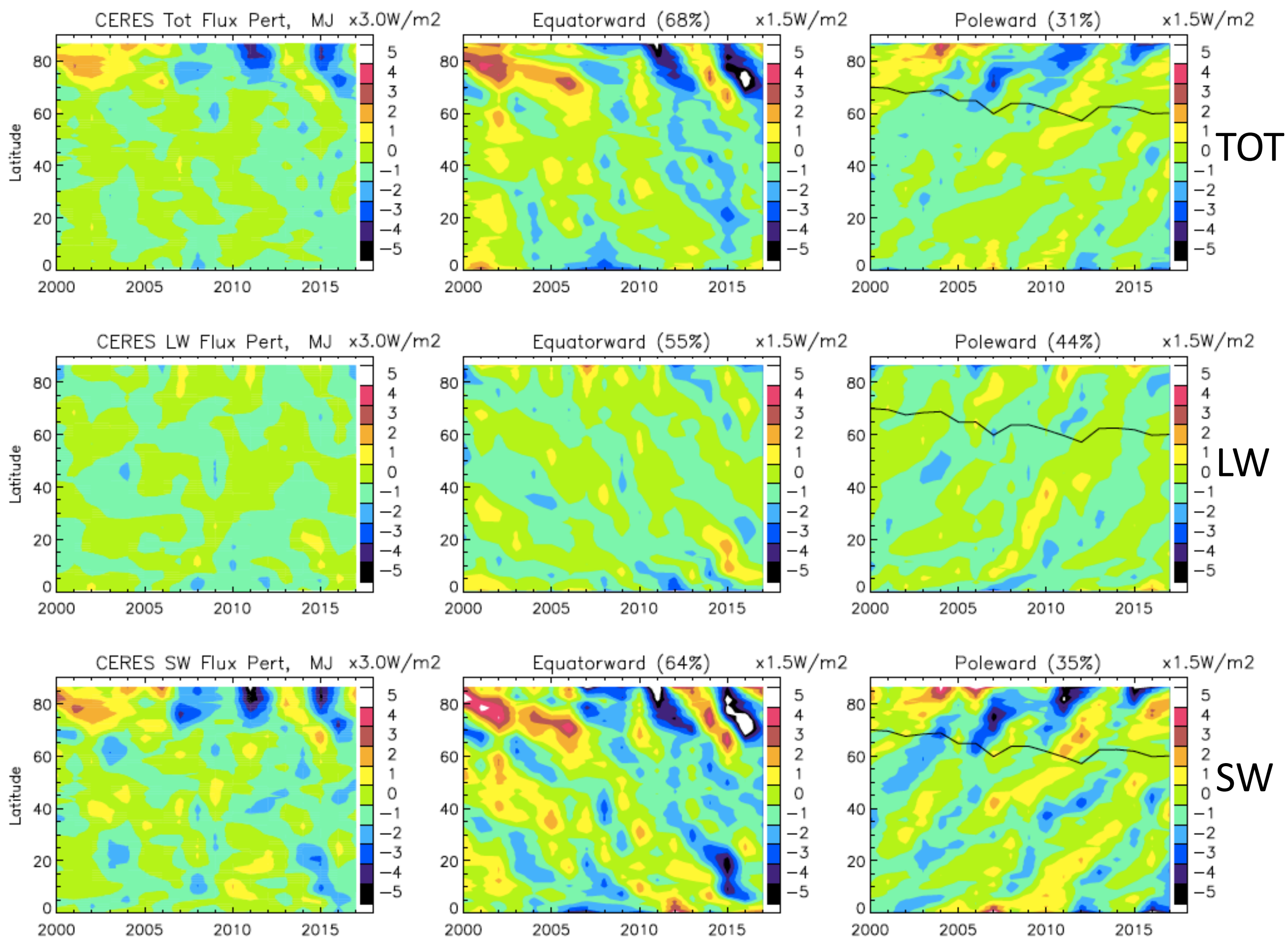


Decomposition of MISR and CERES Albedo Variations



- Stronger (~60%) equatorward component -> polar influence on mid-latitudes
- Coherent patterns at 50^{o}N-60^{o}N
- Increasing oscillations since ~2009 with a period of ~4 years

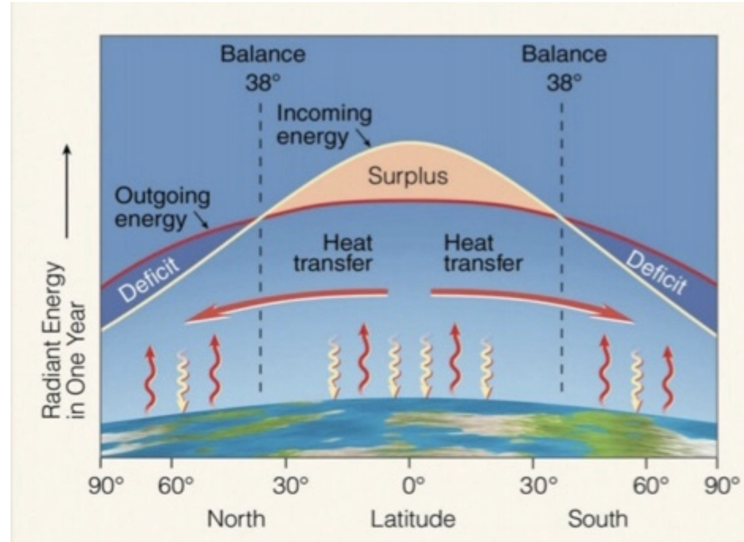
Decomposition of CERES Total, LW and SW TOA Flux Variations

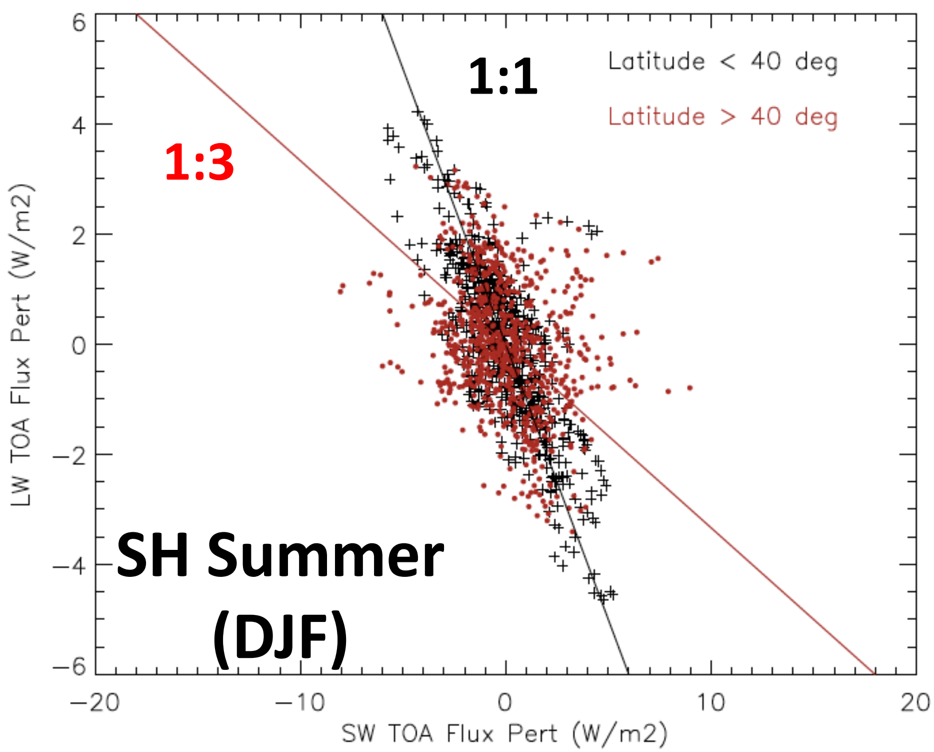


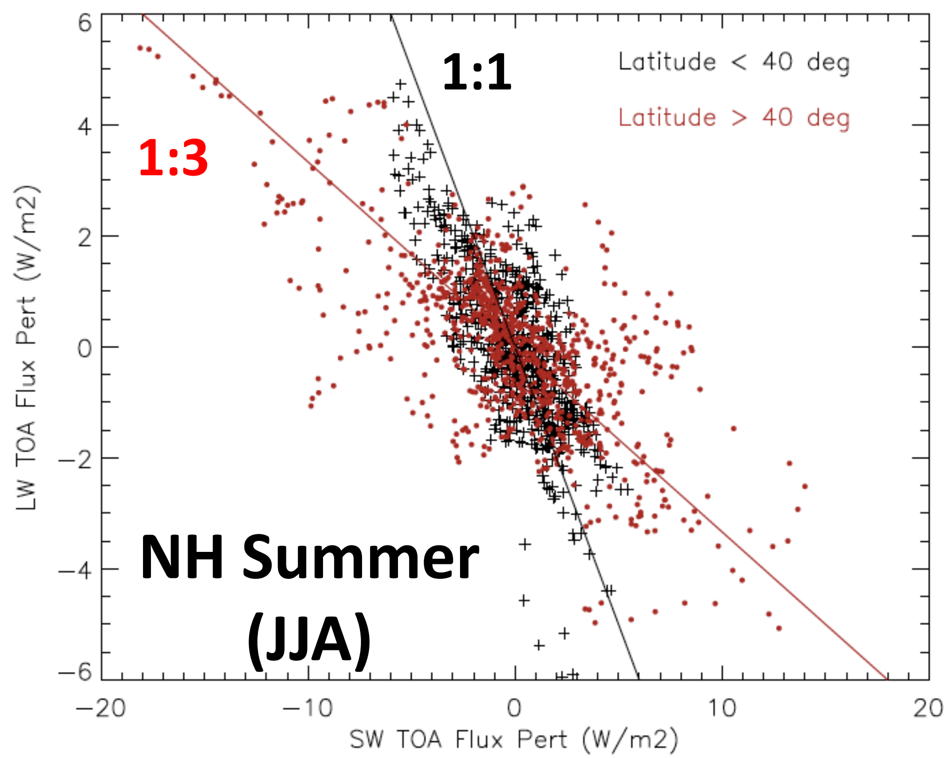
- Summer (JJAS) Total flux dominated by SW flux variability
- Similar equatorward component in Total and SW variability, showing 4-yr oscillations after 2009
- Anti-correlation between LW and SW oscillations in each component

Anti-Correlation
Between Outgoing LW and Reflected SW TOA Fluxes

- LW and SW flux variabilities:
  - Tropics: clouds
  - NH: clouds, lands, sea ice
  - SH: clouds, sea ice







Cause(s) of meridional progression in TOA flux perturbation?

- Atmosphere has short-term heat storage.
- Cryosphere-ocean-atmosphere interactions (e.g., constructive resonance)?
- Arctic/Atlantic Oceans (e.g., storage and transport)?

Concept of “Center of Action”

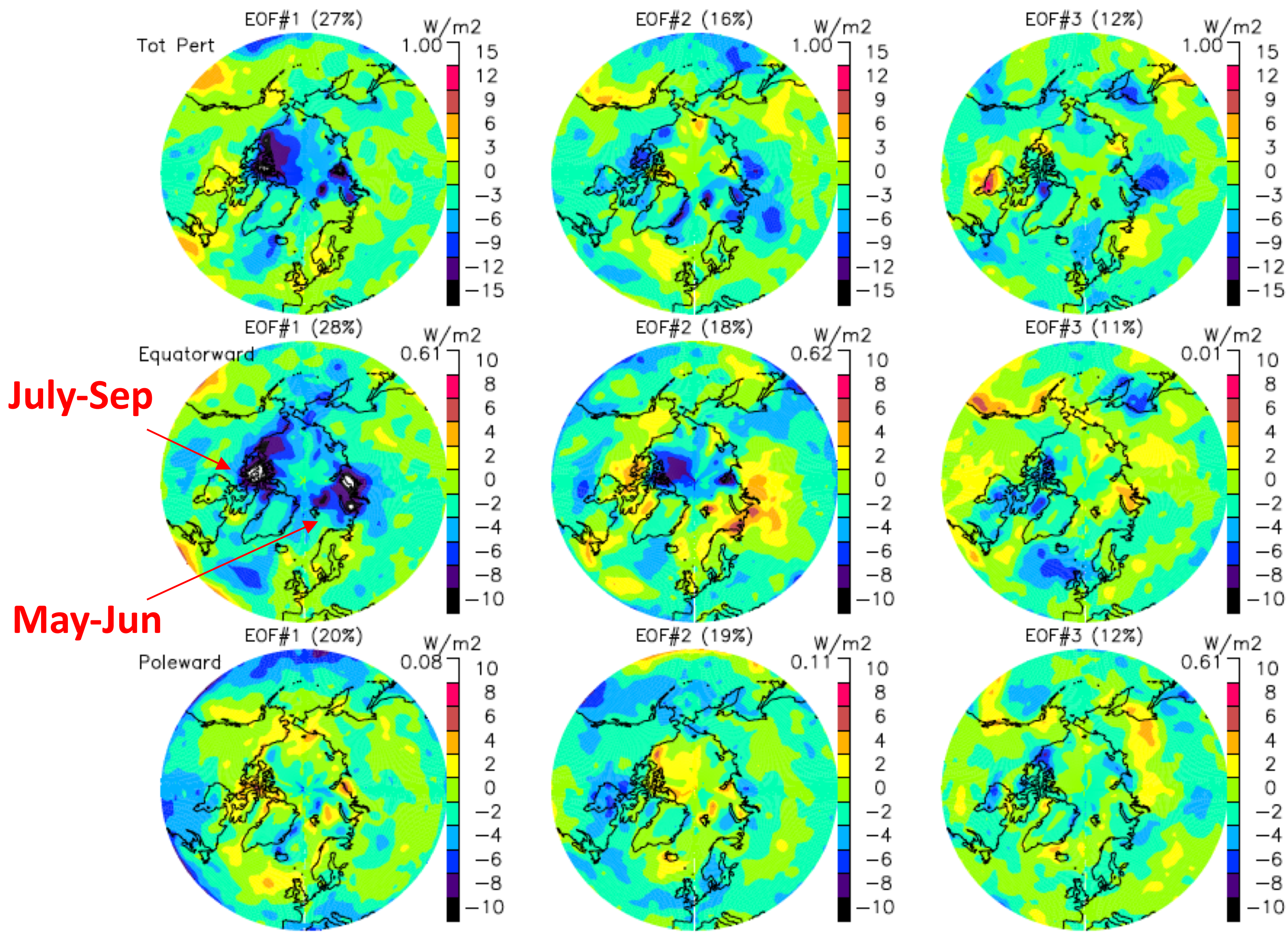
- Max and min pressures (Teisserenc de Bort, 1881)
- Southern oscillation (Gilbert Walker, 1925)

Steps in CERES flux analysis:

1. Apply decomposition analysis to each longitudinal monthly means instead of zonal means
2. Apply EOF analysis on equatorward and poleward components separately

Patterns of Interannual TOA Flux Oscillations (June-September Averages)

EOF#1 EOF#2 EOF#3

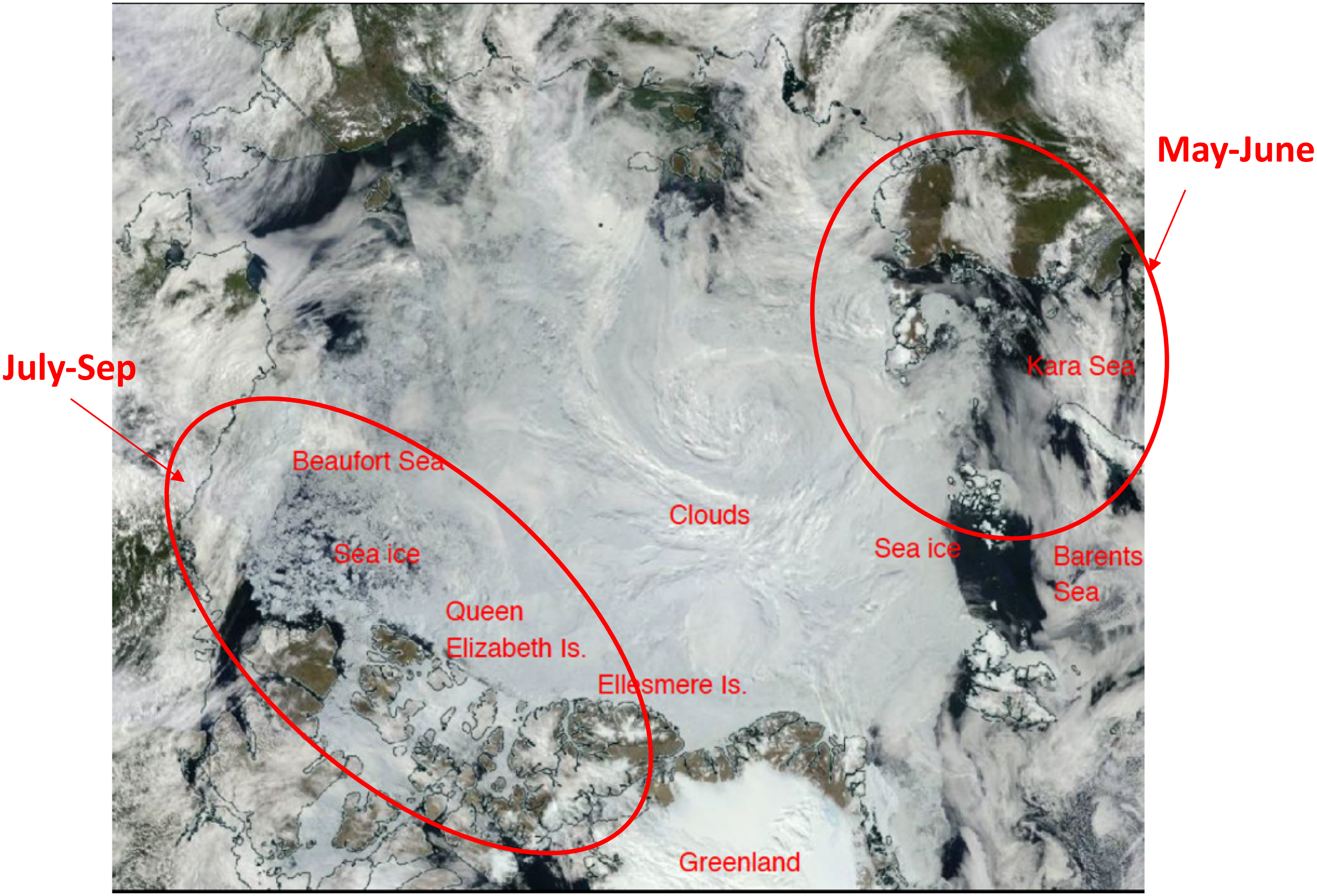


TOT Flux Perturbation

Equatorward

Poleward

July 19, 2015


May-June
July-Sep
Beaufort Sea
Sea ice
Queen
Elizabeth Is.
Ellesmere Is.
Clouds
Sea ice
Kara Sea
Barents
Sea
Greenland

Summary

- Coherent interannual oscillations in summertime Arctic and subarctic TOA fluxes.
- Decomposition into equatorward and poleward components, to identify processes affecting mid-latitude.
- Intensified equatorward progression after 2009 with a period of ~4 years.
- Two centers of action emerge from EOF analysis: Beaufort Sea to Queen Elizabeth Islands (BS-QEI) and the Barents-Kara Sea (BKS).